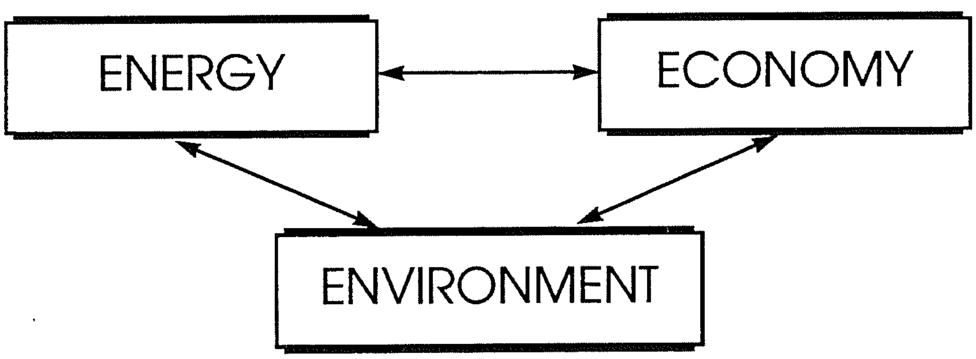
Appendix D

MARKAL-MACRO:

A Policy Assessment Tool to Support Decision Making



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MARKAL-MACRO:

AN ENERGY-ECONOMY-ENVIRONMENT OPTIMIZATION MODEL

Background

Since the mid-1970's, energy system analysts have been using models to represent the complexities of interactions in energy systems to help shape policy. Since the mid-1980's, heightened awareness has made it necessary also to consider the environmental impacts of energy policies. In the 1990's, the economic implications of the now closely-tied energy-environment policies have become of increasing concern to policy makers. In addition, national energy policies are taking on global implications as international discussions regarding climate change and sustainable development continue. The result is that the decision-making process has become increasingly complex and more difficult to understand.

So what is a decision maker to do, who is looking for insights to guide future energy policy? How can technological and policy options be evaluated? Which choices are robust under future uncertainties? What is the effect of emission reductions actions on the economy? How does one country's costs and mitigation potential stack up against another? There is general agreement that a systematic analytical approach is required to examine these questions. Through continuing international commitment the MARKAL model (Fishbone, et al., 1983) has demonstrated its ability to evolve to meet the constantly expanding needs of policy, helping to guide the evolution of numerous energy systems around the world.

MARKAL is a cost-minimizing energy-environment system planning model used to explore mid- to long-term responses to different technological futures, emissions limitations, and policy scenarios. MARKAL-MACRO (Manne and Wene, et al., 1993) is an extension of MARKAL that integrates these capabilities directly with a neoclassical macroeconomic growth model. By combining "bottom-up" engineering and "top-down" macroeconomic approaches in a single modeling framework, MARKAL-MACRO is able to capture the interplay between the energy system and the economy, allowing the affects on demands of endogenously determined energy prices to be explored.

MARKAL was developed in the late 1970's at Brookhaven National Laboratory (BNL) and Kernforschungsanlage Julich (KFA), in West Germany, as part of a collaborative effort under the auspices of the International Energy Agency (IEA). Since then, the model has been applied around the world at the national, regional, and local levels. It is in active use or in an active state of development in 25 countries , including twelve countries of the Organization for Economic Co-operation and Development (OECD), developing countries (e.g., Colombia), rapidly developing countries (e.g., Taiwan), countries in transition (e.g., Czech Republic), and OPEC Countries (e.g., Kuwait).

The recent upsurge in the number of institutions turning to MARKAL can primarily be attributed to three developments:

- The entire modeling system now runs on high-end personal computers, dramatically reducing the cost of setting up and running the model;
- MARKAL-MACRO's integration of energy, environment and economic issues provides the widest coverage of any such methodology generally available; and
- The model is encapsulated in a user-friendly analyst's support "shell", the MARKAL User's Support System (MUSS), which is specifically designed to foster the productive application of the model.

One other reason for the increased interest in MARKAL-MACRO relates directly to the need for countries to conduct consistent and comparable analysis to support the development of national action plans as part of the United Nations Framework Convention on Climate Change. As the countries of the world search for equitable approaches to addressing the potential problems arising from global climate change, the need for countries to communicate the technical basis upon which declared emission reduction costs are based will be an integral part of the discussions. This will become even more important when the benefits of joint implementation approaches between countries are evaluated. With MARKAL-MACRO encompassing the entire area of study, and determined to minimize total energy system costs, it provides important insights for identifying "cost-effective" measures which "ensure global benefit at the lowest possible cost", as called for by the Framework Convention, and fundamental knowledge for shaping any country's (or community's) sustainable development goals.

As part of the ongoing international commitment to the methodology, the participants in the IEA Energy Technology Systems Analysis Programme (ETSAP) have used MARKAL and MARKAL-MACRO to conduct multi-national comparative assessments for over a decade (Kram, 1993). Studies involving a dozen countries have examined the potential role of new technologies, acid rain reduction options, and CO_2 mitigation costs. ETSAP members and other interested parties participate in workshops twice a year to exchange information, establish priorities for continued model development, and define scenarios for their common assessments. In addition, ETSAP publishes a periodic newsletter to keep the growing community of users and policy makers around the world up-to-date on the most recent developments and applications of the model.

Another important benefit arising from the ETSAP collaboration, and the MARKAL community in general, are the large number of national energy systems modelled. Since the databases are all maintained within MUSS, there is a consistent format and user interface to facilitate accessing and using information. This means that there is an extensive pool of technology characterization data, including performance and cost information, readily accessible. MUSS further assists with the task of building new models and conducting comparative assessments by allowing data and results from different countries to be simultaneously reviewed.

MARKAL Model Description

MARKAL is a dynamic linear programming model that optimizes a network representation of an energy system (Fig. 1). The entire energy system is included in the network, from resource extraction through energy transformation and end-use devices to demand for useful energy services. Each link in the network is characterized by one or more technologies available to the model. Many such energy networks, or Reference Energy Systems (RES), are possible for each time period. MARKAL creates the "best" energy system network for each time period by selecting the set of options that minimizes cost, optimizing over the entire time horizon subject to constraints.

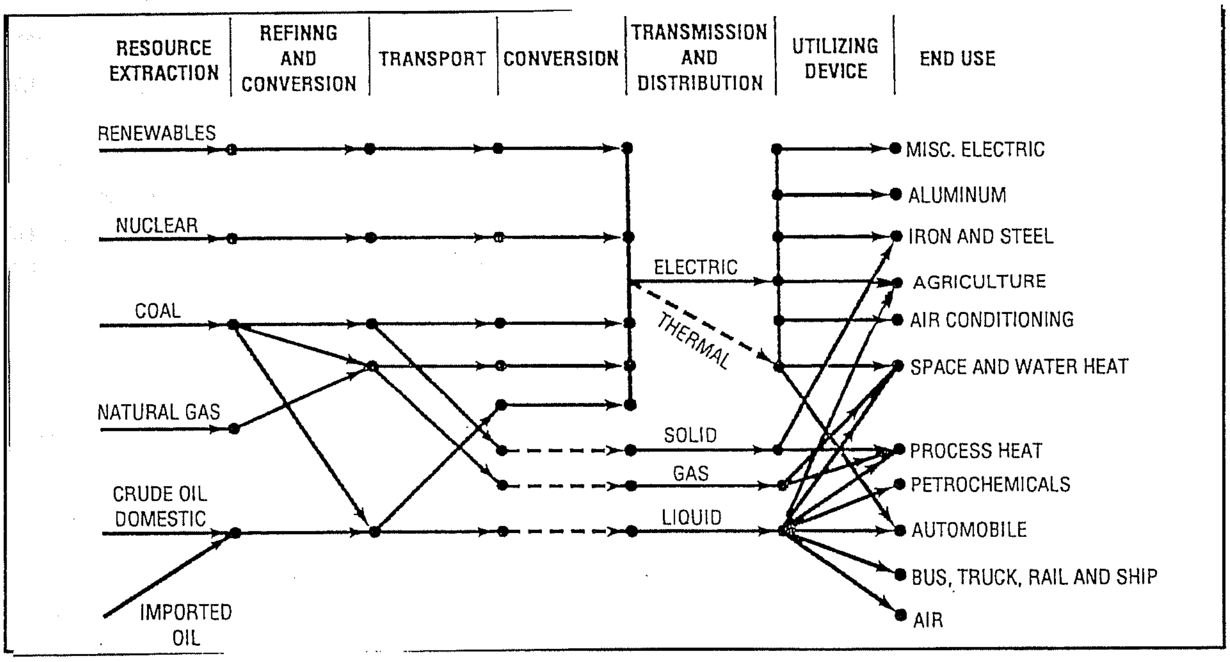

Figure 1 - Simplified Reference Energy System

For any application of MARKAL, the level of detail represented in the model will be primarily a function of the complexity of the energy system, the availability of data, and the policy questions to be addressed. There is complete flexibility with respect to the structure of the RES depicted in the model. The many MARKAL databases available around the world serve as excellent starting points for development of new models, as well as providing default data on technology characteristics and costs while country-specific data are being developed.

MARKAL is a technology-oriented model that deals evenhandedly with supply- and demand-side options. Resource supplies are represented by a series of supply curves indicating the resources available at given prices. For technologies, the key input data required are the fuel(s) used and/or produced, investment and fixed and variable operating costs, technical characteristics such as efficiency and availability factors, market penetration limitations, and environmental indicators such as emission coefficients and land use. Most data can be varied over time to represent changes in system characteristics.

MARKAL is driven by a set of demands for useful energy services specified exogenously by end-use category for each time period. Demand levels are determined from information on such things as the square footage of housing heated and vehicle miles traveled. End-use energy conservation measures such as building insulation and lighter automobiles are treated as conservation technologies, meeting part of the sector energy demand with a dummy fuel, "conservation." This allows internalized selection of conservation technologies in the model. Mitigation options that represent the introduction of new technologies, such as compact flourescent lightbulbs, are depicted just like any other option available to the model. They are evaluated and ranked by the model according to their cost, efficiency and environmental benefit.

The current U.S. MARKAL model consists of approximately 40 demand categories, 100 resource supply options, 210 supply-side technologies, and 330 demand-side technologies. The resulting model contains about 7000 linear constraints. A typical set of 4 sensitivity runs that limit CO_2 emission levels from unconstrained to a 20% reduction runs in about 40 minutes on a 486/66 personal computer. Considering that overnight turnaround on mainframe computers was the norm just a few years ago, the current performance is truly remarkable.

MARKAL solutions include all details on the configuration of an optimal reference energy system. These include primary energy mix, fuel mix, and technology mix (capacity and activity of each technology), along with all direct investment, operating, and fuel costs. In addition, one of the benefits of using an optimization framework is that the marginal cost of each technology, fuel, and environmental constraint is also available. The marginal cost is an indication of how much less the total energy system would cost if one more unit of some desirable model component (e.g., cheap gas supply) were available. Thus a merit ranking, or relative attractiveness of each supply option and technology is determined directly by the model, not required as an input as with other methodologies.

Working with MARKAL is made easier by MUSS, a highly interactive relational database and post-optimization analysis support system. MUSS manages all the information needed to formulate a model and conduct sensitivity analyses. It enables users to cascade through reference energy system diagrams, allowing analysts to see interrelationships among fuels and technologies quickly and easily. The most powerful features of MUSS are its numerous "touch-of-a-button" graphic displays for comparing results from multiple runs. MUSS provides users with a set of standard graphs (Fig. 3-9) and a simple yet sophisticated mechanism for creating customized graphs to meet special needs. This capability to display results from a number of runs simultaneously is a key to analytical productivity. Regardless of the model used, a major analysis such as a mitigation options costing study, will involve many (perhaps 100) runs to calibrate a model, to conduct sensitivity runs, and to gain confidence in and full understanding of the results. The ability to see differences among runs quickly and easily and to convey these differences and their implications to policy makers is paramount for the successful application of large models.

MARKAL-MACRO Model Description

There have been ongoing discussions over the past decade regarding the merits of "bottom-up" engineering models versus "top-down" macroeconomic models. "Bottom-up" models are rich with technology detail and have proved useful for deciding among alternative technologies, especially supply-side technologies, in national or utility-level investment and R&D planning. Their application has been more controversial when dealing with end-use technologies, where consideration of consumer behavior is more important. "Top-down" models focus on the interaction between the energy system and the rest of the economy. They generally predict future demands for electricity and various fuels and may consider effects on employment and economic health of energy industries such as petroleum, coal mining, or electric utilities. They provide little or no information for technological decisions such as whether it is better to invest in wind, solar thermal, or natual gas plants over the next decades.

The current consensus, and the recommendation of the United Nations Environment Programme (UNEP, 1994), is that a combined or hybrid approach is the best way to evaluate mitigation options. MARKAL-MACRO is such a hybrid model. As shown in Figure 2, it combines MARKAL and MACRO, a single producer/consumer macroeconomic model first developed by Professor Alan Manne in his ETA-MACRO model(Manne, 1977). The principle differences between MARKAL-MACRO and ETA-MACRO are:

- MARKAL-MACRO retains all the richness and flexibility of MARKAL in depicting details of an entire energy system; and
- In MARKAL-MACRO, demands for useful energy services (rather than final demands) are linked between the sub-models.

Since MACRO requires a limited set of additional data, once a MARKAL model is in place, moving to MARKAL-MACRO is a logical advancement. Both MARKAL and MARKAL-MACRO are run from the same database within MUSS.

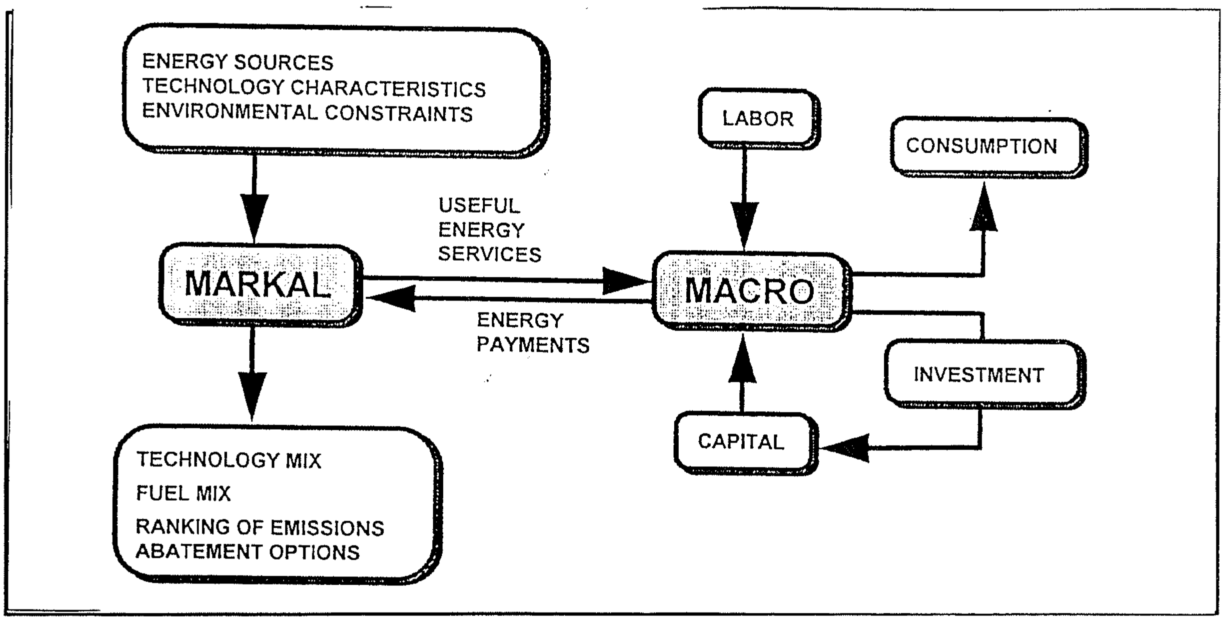

Figure 2 - An Overview of MARKAL-MACRO

By combining “bottom-up” and “top-down” approaches in a single model, MARKAL-MACRO redresses the shortcomings while retaining the merits inherent in each of the approaches. The integrated model simultaneously solves for energy and economic components using non-linear optimization. It extends the coverage of the model to include impacts on the overall economy (i.e., GDP) due to changes in the energy system, and *vice versa*. It does so by means of an endogenous feedback of the costs of meeting energy demands (and thus the prices of energy) between the energy system and the economy. By addressing both perspectives MARKAL-MACRO serves as a tool for promoting dialogue, rather than confrontation, between the engineer and the economist.

With "bottom-up" models, if a new technology is superior in cost and efficiency compared to existing technologies, these models generally show the new technology replaces the old. Other attributes of a technology, such as quality, convience, or aesthetics are usually ignored. In "top-down" models, on the other hand, macroeconomic approaches focus on historical patterns of consumer behavior, and tend to avoid technological details. For example, "bottom up" models typically indicate the availability of considerable "free," i.e., cost effective, conservation opportunities. "Top-down" models tend not to find such savings available. There are many explanations of the reason for this difference. One important reason is that the "top-down" models focus on behaviorial factors exibited in consumers' historical conservatism in investing in new energy saving technologies while the "bottom-up" models focused primarily on the potential cost savings. In addition, "bottom-up" models generally focus on societial benefits and ignore consumer risks.

MARKAL-MACRO can explore these questions fully within one model. Technological conservation (hardware requiring investment, e.g., more efficient air conditioners, better building insulation) are explicitly characterized in MARKAL. But, when the "bottom-up" side of the model says, "lets buy more of this energy efficient technology because total life-cycle costs will be lower," the MACRO side says, "Oh, costs will be lower, we can use more energy." Thus MARKAL-MACRO captures this realistic tension between supply and demand.

MARKAL-MACRO also builds in the capability to include consumer conservatism in the form of hurdle rates, which make the model consider the consumer viewpoint instead of the societal view. These hurdle rates represent the affect on consumer behavior resulting from the combination of lack of information, lack of ready cash or available credit, adverson to risk, and other factors that lead the consumer not to buy devices that the "bottom-up" analyst assumes they will buy. By evaluating the affects of adjusting the hurdle rates proponents of incentive programs to make realistic estimates of their likely costs and benefits, and effectiveness.

To realize MARKAL-MACRO, MARKAL was re-written in GAMS, the General Algebraic Modeling System (Brooke, A., et al., 1988). GAMS is an extremely flexible and widely available modeling language that can be used for a wide range of applications in addition to MARKAL-MACRO. The new modeling platform has made it much easier to make enhancements to the model, enabling it to represent better the issues that concern policy makers. Besides the recent addition of consumer hurdle rates mentioned above, enhancements planned for the near future include an expanded representation of the electric system, material flows, and multiple financial sources. Other desirable modeling features are expected to be identified during the process of applying the model in new environments.

Research continues with MARKAL-MACRO. At the University of Geneva, in Switzerland, decomposition methods are being used to allow simultaneous solving of multiple MARKAL models with a single CO_2 emissions constraint. This permits examination of collective approaches to reducing greenhouse gas emissions. At Brookhaven National Laboratory, this pioneering work may continue by moving to massive parallel computers with an eye towards solving many (perhaps 40) national models simultaneously to examine in detail the potential for co-operative strategies for reducing global emissions. In conjunction with professor Alan Manne, Brookhaven National Laboratory is also exploring ways of incorporating MARKAL-MACRO into a world trade model. One of the benefits of such a model is a capability to examine trading of energy carriers, such as oil and gas, and energy-intensive products, such as steel and aluminum, along with the possible relocation of energy-intensive industries. In addition, international fuel prices are determined by the model, rather than specified exogenously, reducing the uncertainty associated with projected future prices of fuels that often plagues such models. At the University of Pennsylvania and the Univerisity of Geneva, methods are under development to introduce stochastic inputs to MARKAL to account uncertainties in future projections of important variables such as end-use demands and fuel prices.

Application of the Methodology for Mitigation Costing Studies

The United Nations Framework Convention on Climate Change calls for parties "to take precautionary measures to anticipate, prevent or minimize the causes of climate change and mitigate its adverse effects ... taking into account that policies and measures to deal with climate change should be cost-effective so as to ensure **global benefits at the lowest possible cost.**" To comply with these recommendations, countries must quantify costs and evaluate alternatives, necessitating use of some kind of modeling approach.

Why is MARKAL-MACRO so appropriate for this task?

First, MARKAL is a well-proven methodology that is readily available around the world. It has been used extensively for multi-national comparative assessments by the IEA-ETSAP. Now ETSAP and most other MARKAL users are moving to MARKAL-MACRO. From an analytical perspective, it does much more than just calculate flows and compare directly competing technologies. Since MARKAL-MACRO represents the entire energy system and its interactions with the economy in an optimization framework, choices are made on a system-wide basis. That is, it automatically evaluates the benefits of each option taking into consideration technology characteristics, fuel costs, up/down stream energy supply and conversion costs, competition between technologies and demand sectors, and impacts on the environment and the economy. For CO_2 emissions studies, it provides as primary results a ranking of the mitigation options, as well as the cost of reducing CO_2 (value of carbon rights) and implications for the economy. When conducting sensitivity analyses based on varying technical or policy options it also indicates the cost of deviating from the least-cost solution. This helps to provide further insight into the consequences of embarking on alternate paths.

Of the many diversified policy analysis issues that MARKAL-MACRO can address, development of least-cost energy strategies and costing studies of mitigation options are two areas where the model excels. Recognizing this, the US Department of Energy is using MARKAL-MACRO in-house for exactly these purposes to perform the analyses mandated in the Energy Policy Act of 1992. The US Environmental Protection Agency is also moving MARKAL-MACRO in-house for similar applications. Other examples of the kinds of applications for which MARKAL has been used include:

Exploring and evaluating new technological options, determining potential returns (financial and environmental) on investments;

- Determining the most cost-effective way to meet heating demands by comparing additions to district heating and co-generation plants versus subsidizing home insulation;

- Identifying the economic, security, and environmental consequences of a nuclear power phase-out to quantify increased costs of alternatives;
- Exploring different energy-related pollution control policies (e.g., carbon taxes) to determine costs of compliance and shifts in patterns of energy use;
- Identifying cost-effective ways to reduce greenhouse gas emissions to help justify requests for investment capital from international funding sources; and
- Exploring technological, economic, and environmental consequences of potential shifts in patterns of energy use, such as shifts in transportation mode, changes in industrial mix, and introduction of energy conservation and new energy use patterns in buildings.

To summarize, in the context of the recommendations of the Framework Convention and to foster the building of in-country capabilities for conducting energy policy analysis over the long-term, MARKAL-MACRO can assist by:

- Providing an integrating framework for the logical organization and visualization of an energy system;
- Developing consistently reproducible inventories and future projections of greenhouse gas sources and emissions;
- Evaluating the potential role and comparative cost-effectiveness of new energy technologies in different future scenarios;
- Providing a merit ranking of mitigation technologies to help guide priorities for seeking foreign investment and promoting technology R&D;
- Quantifying the cost of reducing emissions (e.g., CO_2-abatement cost curves);
- Exploring possible strategies (e.g. carbon tax) for reducing CO_2 emissions;
- Development of hedging strategies for emission reduction;
- Providing an indication of the economic impact (e.g., GDP growth) of strategies to reduce emissions and other energy/environment policies;
- Providing a country with a sophisticated, well documented, easy-to-use, proven methodology; and
- Bringing a country into the international dialogue on climate

change using a common language" to facilitate acceptance of findings and comparison among countries.

With MARKAL serving a common framework for depicting an energy system and MUSS holding the data in a consistent format, the system can be used to compare independent results between countries quickly and easily on the same graph. ETSAP has repeatedly demonstrated the ability to conduct multi-national comparative assessments in just this manner.

Including MARKAL-MACRO among the tools available to a country can provide added insight into cost-effective paths for future development of an energy system. The information obtained from the model is exactly the kind policy makers need to help formulate a national action plan for the Framework Convention and to maintain a continuing capability to assess this and other issues related to environmentally responsible sustainable development.

A Practical Example: How to Evaluate a Particular Mitigation Option

Establishing a Reference Case

As a precursor to conducting an analysis of potential greenhouse gas mitigation options a calibrated and validated "reference case" must be established. Working with any modeling system this is an extremely important, and most time consuming step, since anaylses are conducted by comparing the results arising from varying the assumptions between runs. The steps involved include:

- Depicting the reference energy system (RES) by characterizing the currently available technologies and supply options;
- Identify what energy services demands are to be meet and develop projections for future demands;
- Include any new technologies that are expected to be available within the study period, and adjustments to the characteristics of existing technologies and supply options (e.g., lower cost, higher efficiency);
- Run the model adjusting the energy system depicted in the initial period such that historical primary energy mix, fuel mix, technology mix, prices and emissions are matched;
- Examine the choices made by the model for future years to identify any unreasonable situations (e.g, moving all transportation to bicycles) and restrict the model accordingly; and
- Subject the model assumptions and initial results for expert review and comment.

Each step of the way MUSS has numerous features to assist the analyst with carrying out the tasks described. Once an acceptable "reference case" is established the real work of using the model to conduct an assessment can begin.

Lighting Example

To illustrate what is required to conduct an assessment an extremely simplied RES for the country UTOPIA is employed. UTOPIA has only three demands categories, eight demand devices and six supply technologies. The case names appearing on the MUSS graphs are interpretted as:

- BASE CASE : the "Reference Case"
- BASE -10% C : a -10% reduction in initial period CO_2 levels beginning in the 2nd period
- FLIT CASE : the compact fluorescent lightbulb base case
- FLIT STABLE : the compact fluorescent lightbulb with a steady level of CO_2
- FLIT -10% : the compact fluorescent lightbulb with -10% initial period CO_2 levels

The steps below, and accompanying graphics, provide an indication of how the potential benefits and costs of promoting the introduction of compact fluorescent lightbulbs to help achieve a desired CO_2 emission reduction target of 10% might be evaluated.

- From the results of the "reference case" calculate the level of CO_2 emissions which is 10% below the level obtained in the initial (historical) year;
- Introduce the compact fluorescent lightbulb to the RES, as depicted in Figure 3, by simply copying a similar existing technology (e.g., standard incandescent lighting) and adjusting the cost, efficency and lifetime, but restrict its availability;
- Run the reference case specifying limits on future emissions equal to that calculated in the first step;
- Remove the limit on the availability of the compact fluorescent lightbulb and run both the unconstrainted and limited emissions cases, plus a stabilization case;
- As described in the text associated with each of the MUSS analysis graphs evaluate the impact on the energy system.

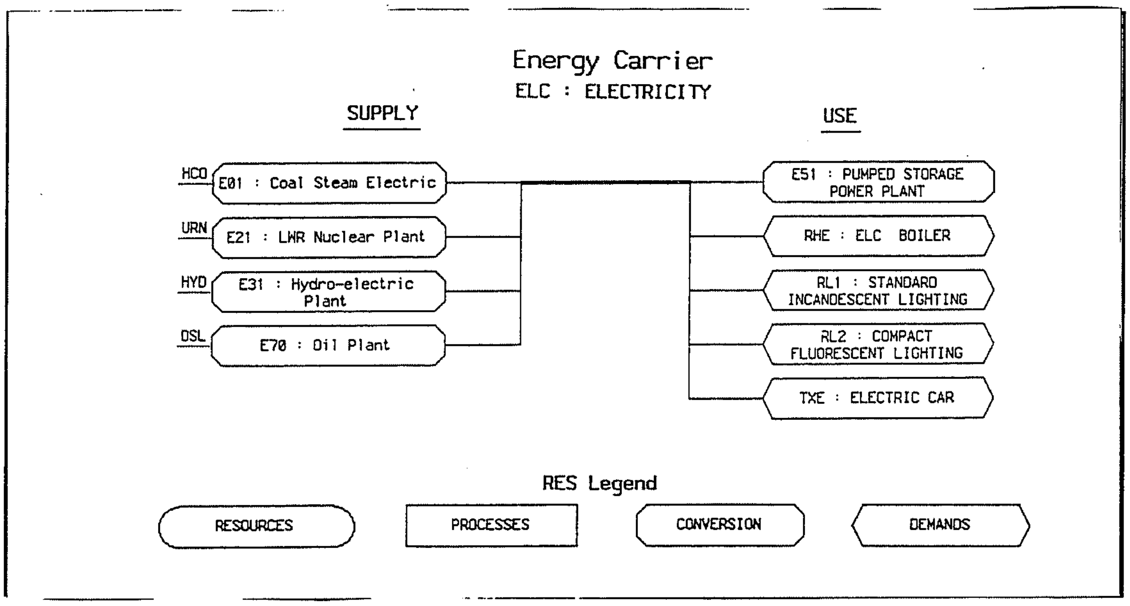

Figure 3 : RES of the Electricity Subsystem

The UTOPIA technologies which produce and consume electricity are shown in the above reference energy system diagram. Note also that the fuels associated with each supply technology are also shown. The user can easily cascade through the RES to gain an indepth understanding of the interrelationship in the network.

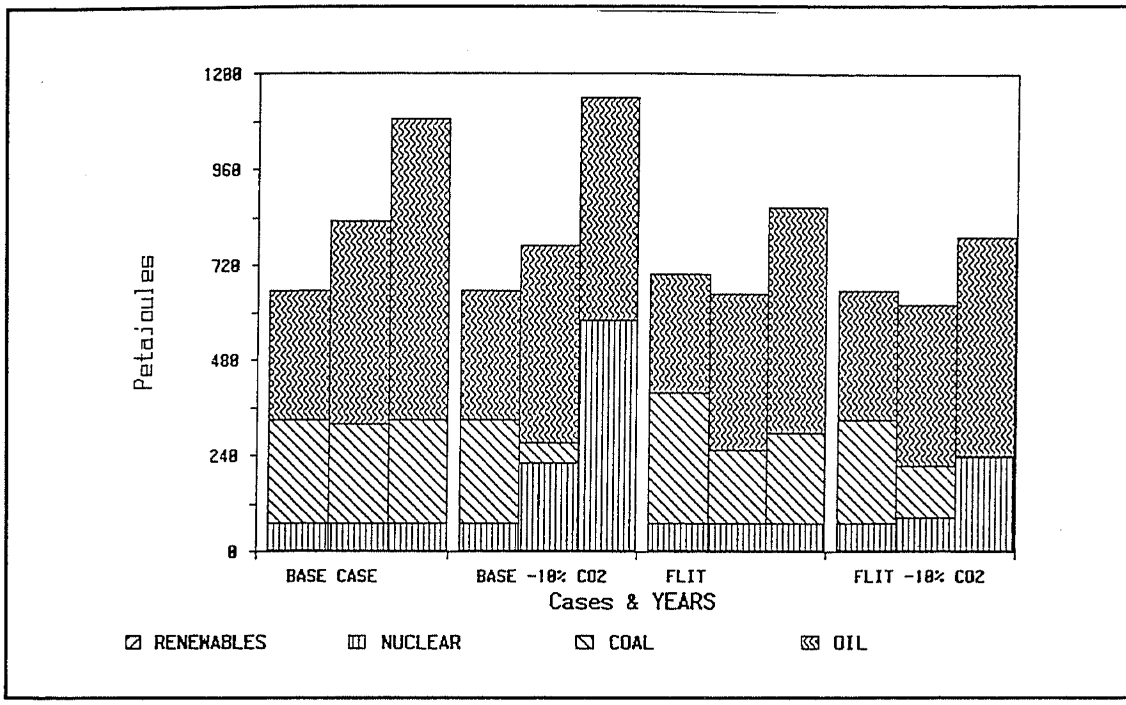

Figure 4: Primary Energy Input

The Primary Energy Input graph shows that the introduction of high efficiency compact fluorescent lighting greatly reduces the primary energy demand (BASE cases vs FLIT cases). Without compact fluorescent lights, nuclear energy increases drastically, replacing cheap coal in order to meet a 10% CO2 reduction from the base year level (BASE -10% C). However, with compact fluorescent lighting, the decrease in electricity demand allows more coal to be used under the same carbon emission constraints (FLIT -10% C).

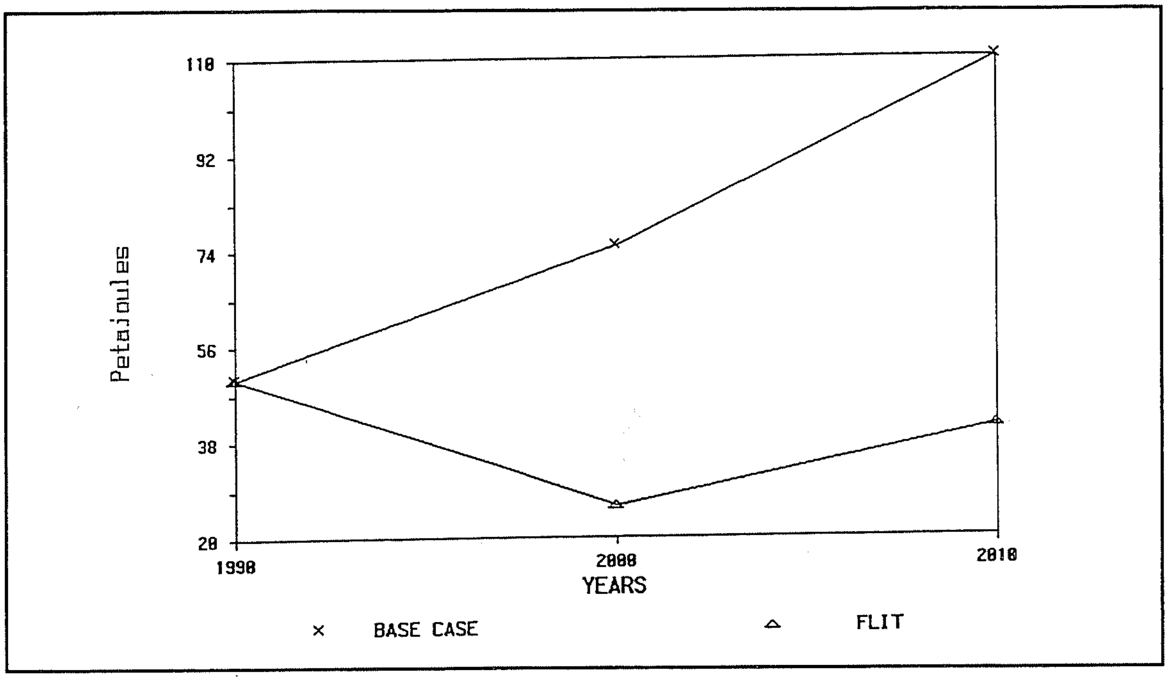

Figure 5: Electricity Demand for Lighting

The demand of electricity for lighting is projected to be much lower in the case with compact fluorescent lighting (FLIT) than that of the base case (BASE), even without any emissions constraint. This is due to the fact that fluorescent lighting is five times more efficient than the standard incandescent lighting.

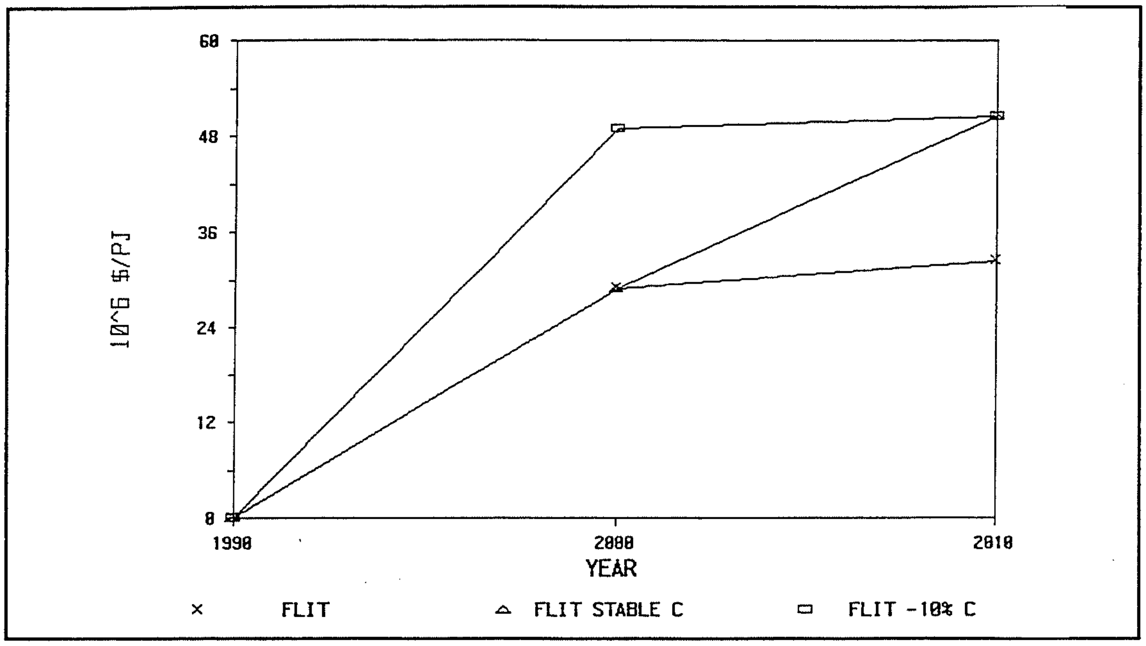

Figure 6: Marginal Cost of Compact Fluoresent

The marginal cost of compact fluorescent lights is a measure of the desirability of a technology and indicates the reduction in total system cost if one additional unit of this technology becomes available. The graph shows that the technology is viewed of by the model as extremely valuable, even before emission restrictions are applied. Furthermore, the marginal cost increases as the carbon limits become more restrictive, indicating the technology has increasing value to the energy system with decreasing carbon emission limits.

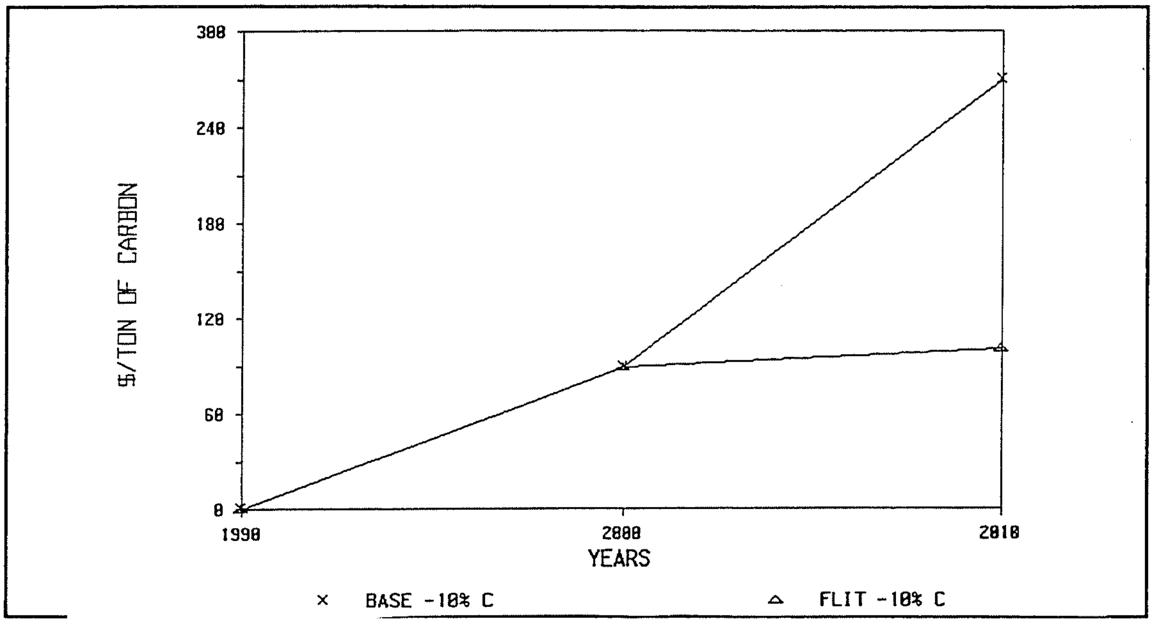

Figure 7: Value of Carbon Rights

The value of carbon rights, or cost of avoided emissions, is the marginal cost of reducing one unit of carbon emission at each equilibrium state (optimal solution). The graph shows that these marginal costs are much lower between the years 2000 and 2010 in the 10% carbon emission reduction case with compact fluorescent lights (FLIT -10% C) than those calculated in the case without this technology (BASE -10% C). This difference in the cost of avoided emissions is a strong justification for incentive programs and policies facilitate the introduction of the technology.

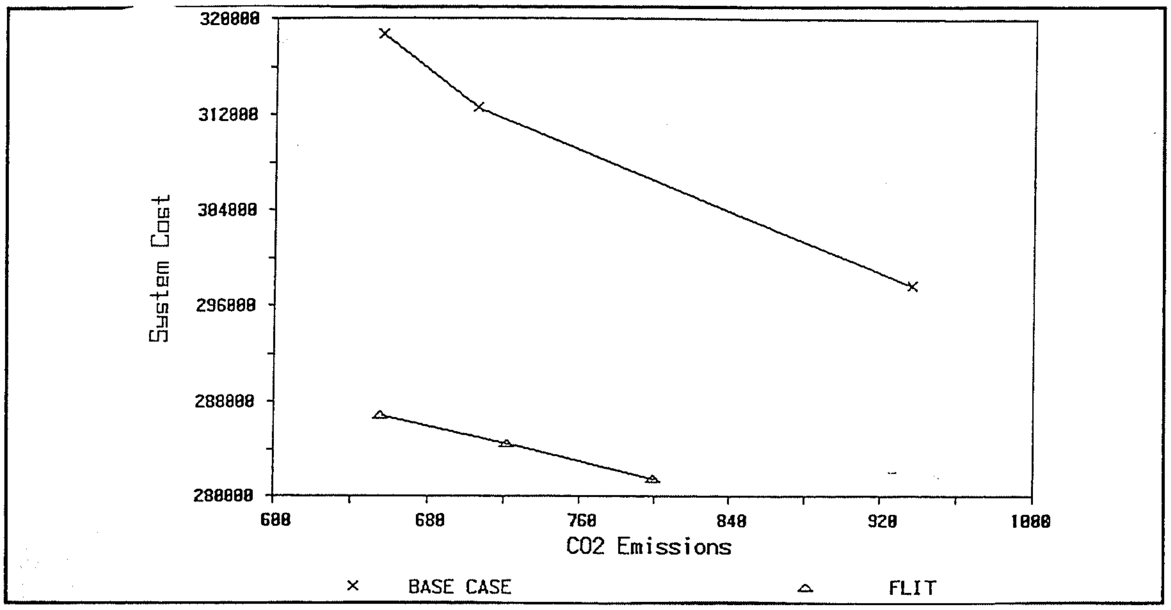

Figure 8: Total Cost vs CO_2 Emissions

Figure 8 depicts the total energy system cost as a function of total carbon dioxide emission generated from the energy sector. It clearly shows that the total cost of reducing carbon emission is much lower in the case with compact fluorescent lighting (FLIT) than that calculated in the base case (BASE). This means that the impact on the economy of such a policy would be less severe if the technology is available. In addition, it also shows that the level of emissions is reduced from that of the business-as-usual case just by making the compact fluorescents lighting available.

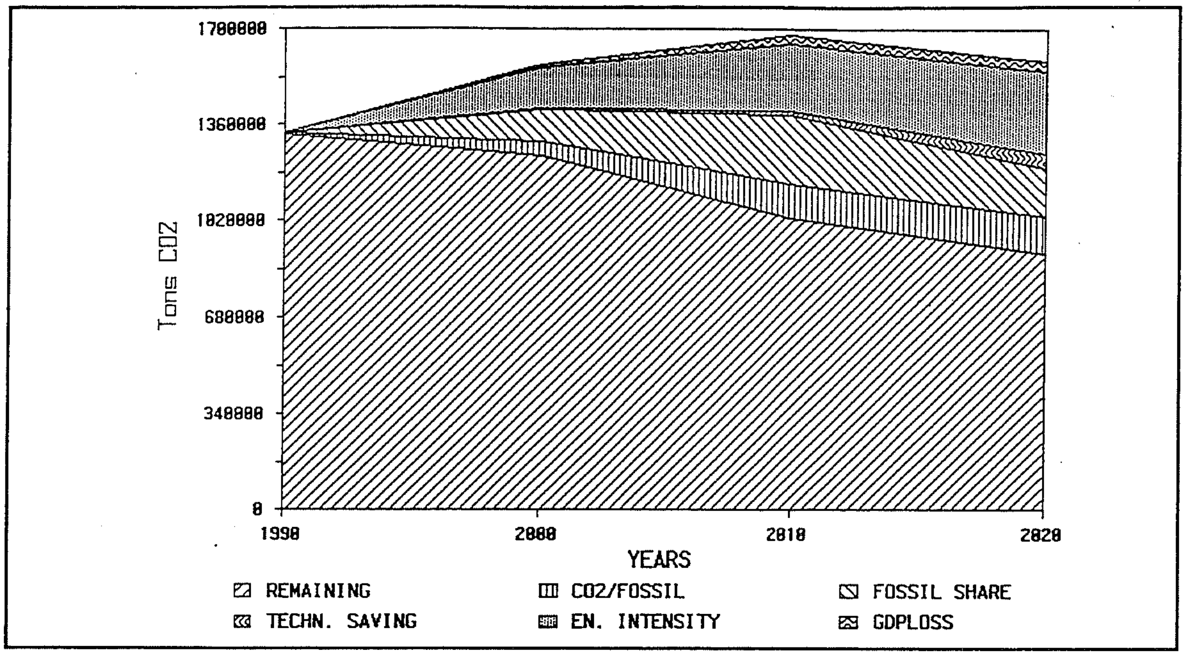

Figure 9: Contribution of Options

The graph, taken from a different analysis than that employed in the examples above, breaks down the total effect on CO_2 emissions between two MARKAL-MACRO cases (with different carbon emission constraints) by five groups of contributing factors. The block labelled "REMAINING" represents the total CO_2 emission of a constrained case (20% reduction beginning in 2010 from the unconstrained case). The cumulative sum of the six blocks represents the unconstrained total CO_2 emissions from the energy sector. The block "CO2/FOSSIL" is the amount of CO_2 reduction due to a shift to less CO_2 emitting fossil fuels. The block "FOSSIL SHARE" is the reduction attributed to the increasing share of non fossil energy. "TECHN. SAVING" is the reduction due to the use of more efficient technologies. The largest block "EN. INTENSITY" is the reduction through substitution (less useful energy demand per unit of GDP). The block "GDPLOSS" represent the CO_2 emission reduction attributable to the loss in GDP.

Besides the sample graphs included above MUSS supports an extensive set of other standard and user-defined analysis graphs that allow the analyst to examine changes in results between model runs quickly and effectively. Up to 10 runs (from different countries is desired) can be compared side-by-side on a single graph. In addition, 'screening' filters allow the user to get directly to desired information. Also, scatter graphs allow for large numbers of model results (up to 50), from multiple runs, to be displayed for visual screening by the analyst to help identify which model components merit more indepth investigation.

MARKAL-MACRO's flexibility and integrated energy-economy-environment model respresenation, combined with MUSS's data and scenario management features and simple but powerful graphic tools result in a hightly productive environment for addressing the issues that confront policy makers now and well into the forseeable future.

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APPENDIX 1.

MARKAL USERS

(**CURRENT**, Former, *Interested*).

EUROPEAN COUNTRIES

Austria
BELGIUM
Denmark
GERMANY
Ireland
ITALY
- **POTWENZA**
- **NAPOLI**

NETHERLANDS
NORWAY
Spain
SWEDEN
- **GÖTEBORG**
- **UPPSALA**
- **VARNAMO**
- Jönköping
- Nässjö

SWITZERLAND
- **GENEVA**

Turkey
UNITED KINGDOM

AMERICAN COUNTRIES

BRAZIL
CANADA
- **QUEBEC**
- **ONTARIO**
- **ALBERTA**

COLUMBIA
Equador
Mexico
UNITED STATES
- **NEW YORK**
- **NY POWER POOL**
- *Pennsylvania*

FAR EASTERN COUNTRIES

AUSTRALIA
CHINA
- Guangdong

INDIA
INDONESIA
JAPAN
- **OSAKA**

S. KOREA
TAIWAN
New Zealand

ECONOMIES IN TRANSITION

CZECH REPUBLIC
ESTONIA
Hungary
Poland
BULGARIA
SLOVAK REPUBLIC
SLOVENIA

OTHER COUNTRIES

KUWAIT
South Africa
Egyptt
TUNISIA
Zimbabwe
Nigeria
ETHIOPIA